Ultrasonic Surface Profilometry User Manual

Processing Front Surface Echo Time-Of-Flight Images To Obtain Surface Depression Profiles

This section describes in more detail the steps necessary to obtain quantitative ultrasonic surface profiles using the Sonix ultrasonic c-scan system and Flexscan software (present version is 4.71a).   The user is expected to have reasonable knowledge of the Sonix c-scan system and Flexscan software, and is referred to the Sonix Flexscan User Manual for more information.

1. Place sample on level, smooth surface support plate. In 'configuration' window from 'Edit' menu item, select '16-bit image type' (see figure C1). In 'feature parameters' window from 'Edit' menu, select 'peak-detection type = threshold' and 'time-of'flight to edge' (see figure C2). In 'scan set-up' window under 'Scan' menu item, set up scan parameters (figure C3). Perform time-of-flight (TOF) ultrasonic scan for a front surface echo waveform off the sample as described in the Procedures section of this report. Make sure to increase the pulser-receiver gain so as to significantly threshold out the echo so as to have a consistent leading positive or negative edge that will be present at all scan positions (as is physically possible; it is recognized that extreme scatter may occur off very rough surfaces causing significant echo attenuation and leading either to no gate intersection with the echo or a significantly different intersection position along the leading edge) (see figure C4). Place time gate in position to intersect leading edge at desired location. At the scan origin, record the exact time-of-flight in μsec where the gate intersects the leading edge by expanding the digital oscilloscope so echo is highly spread apart, and using the 'locate-measure' cursor under the 'Measure' menu item to find this time. Record the z-motor position in mm. Save the image and parameter files.

2. For leveling in conjunction with surface profiles, remove the sample from the support and refocus the transducer at the scan origin onto the support plate by moving the z-axis down (keyboard control) until the leading edge of the front surface echo off of the support plate intersects the gate at the exact same time location (or as close as possible) as that for the scan on the sample. Perform identical scan as that for sample. Save the image and parameter files. Using the 'Add/Subtract' window (Image Combination) under the 'Process' menu item (see figure C5), mouse click on the sample TOF image (in the title bar) and then mouse click on 'Image 1' box in the 'Image Combination' window. Mouse click on the support scan image title bar and then click in 'image 2' field in the 'Image Combination' window. At the top of the 'Image Combination' window, mouse click on the mathematical operator box until a '-' appears indicating image subtraction. Click 'process' in the 'Image Combination' window to obtain a 'leveled' TOF image. Save the leveled image. This image will be of type .cs rather than .cs1.

3. Open 'surface profilometry' window under 'Process' menu item (see figure C6). Hit 'return' key to move between fields in this window. Mouse click on the third box

down from the top of window until 'No Support Info' is displayed. (Since leveling was accomplished with Add/Subtract function, we do not need to consider the support scan information here.) If desired, use mouse cursor to draw 'rubber rectangle' for processing of a sub-area of image rather than the whole image. To use 'rubber rectangle', hit middle mouse button until 'cross' is apparent and then drag mouse over desired area of sample scan to outline the area.

4. In 'surface profilometry' window, mouse click on sample TOF scan image title bar, then click on 'surface scan' box. Hit 'return' key until reaching 'couplant velocity' entry. Adjust temperature-dependent couplant velocity to the measured value or known value. Initially, have 'no bkgd subst' option enabled if no extreme value filtering is needed. Depending on whether sample fills image (no background area) or sample is on background, enable the appropriate option. If rubber rectangle is used, it is likely that it will encompass just a sample area (no background). Have 'filter = off' enabled if no extreme value filtering is needed. Enable 'ascii output' or 'no ascii output' depending on whether it is desired to work with data off-line. When ascii output is generated, 2 text files are created. These are a continuous text file for surface depression profile values (sura.asc) and a text file of columnar format having surface depression profile as a function of x,y scan coordinates (surc.asc). Mouse click on 'begin processing' in surface profilometry window which will generate the surface profile. Toggle on the units box in the upper right hand corner to see maps in terms of (µsec), mm or in. Save the surface depression profile image. This image will be of type .cs rather than .cs1.

5. If extreme value filtering is necessary, use 'Clamp result' and filter = 'extreme value' (see figure C8). Open the 'Palette window' from the 'windows' menu, mouse click on the S8 palette and add a hinge. Mouse click on 'Thr' button at the right of the Palette window to go into threshold mode. Initially, adjust the highest hinge upward so that it is at 100% and the lowest hinge to 0%. Then, adjust the highest hinge downward so that high extreme values to filter are made white and adjust the middle hinge either upward or downward so that low extreme values to filter are made black. Other colors can also be used for preferred visualization in a similar fashion. To use other colors for example, click on the top hinge, and and make it red by moving center cursor notch in hexagon in palette window to the 'R' symbol. The slider control should be set at 100%. Then click on the bottom hinge and make blue by moving the center notch cursor in hexagon to the 'B' symbol. The slider control should be set at 100%.

Then, in the surface profilometry window, adjust 'clamp to palette min' to the % associated with the middle hinge, and adjust the 'clamp to palette max' to the % associated with the upper hinge.

6. For samples having a donut-type configuration (hole in the middle) such as the Baaklini MMC rings, use 'no bkgd subst', 'sample is on bkgd' and 'filter = off'. Filtering cannot be performed on this type of sample.

7. The 'add/subtract' (Image Combination) window can be used further for contrast expansions or adding / subtracting constant values for normalization.

8. Use 'cross-section' from the 'Visualize' menu item to obtain line profiles across the maps as needed.

9. The Sonix Flexscan software allows 3d surface and perspective views for data visualization. These are located in the 'Process' menu. For more detailed 3d visualizations, it is recommended to use 3rd-party software programs such as Visual Numerics PvWave or TableCurve 3d. To get the data off-line, an option in the surface profilometry window to 'write ascii files' is provided as mentioned in step 4.
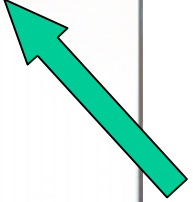
Fig. C1. Configuration window showing set-up for Image Format.
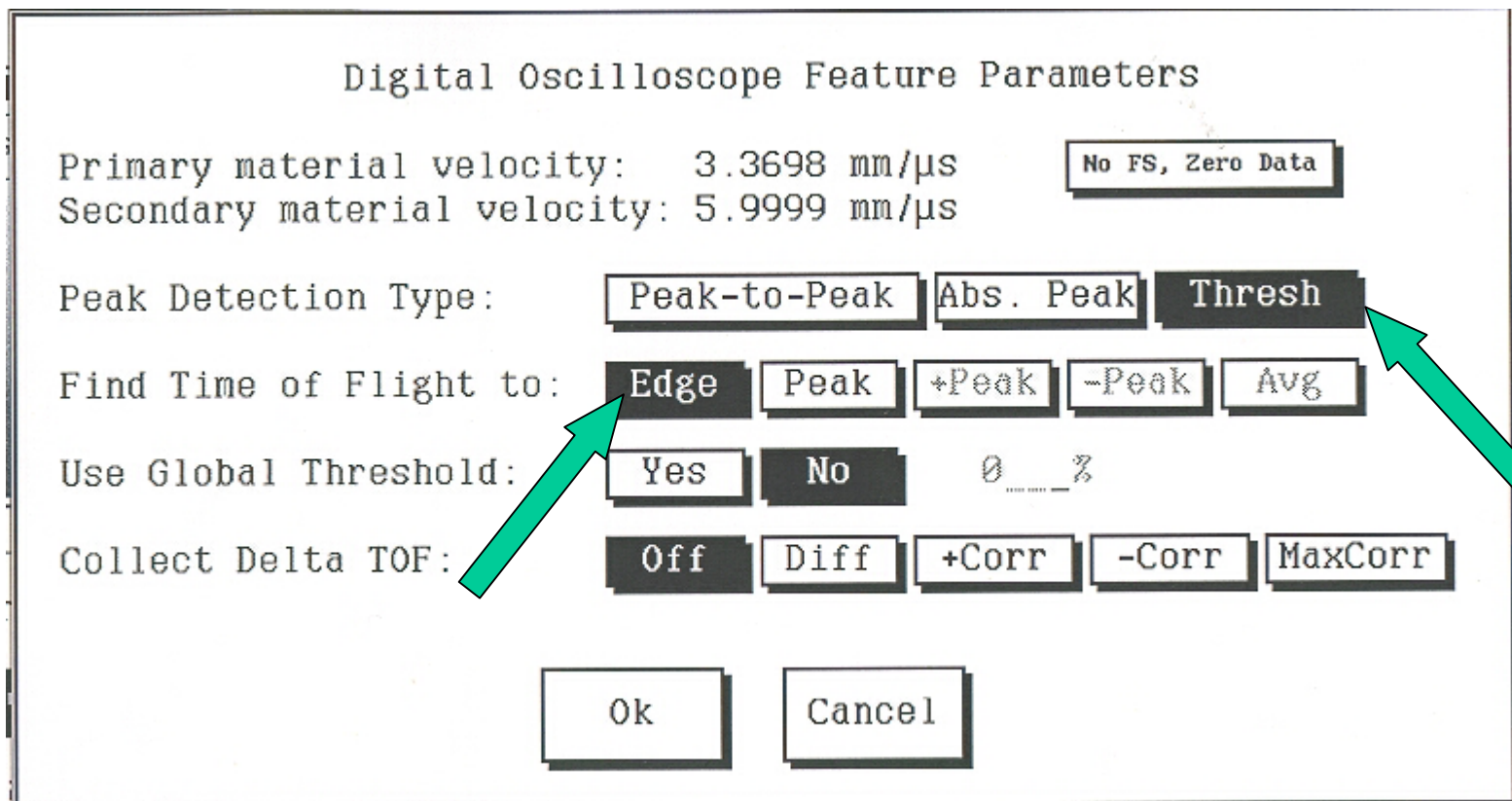
Fig. C2. Feature Parameters window showing set-up for waveform gating options.

SCAN SETUP

| Point | B-Scan | **Linear** | Cylindrical | Polar | Surface |

Scan Axis: ⇕ X-Axis ☐ Locked

Step Axis: ⇕ Y-Axis ☐ Locked

| Scan Dimensions: 418 x 418   Pixels |
| Scan Time: 54:29   Size: 0.2   MB |

Scan Axis Length: ⇕ 39.8145   mm   Scan Direction: **Pos** | Neg

Step Axis Length: ⇕ 39.8145   mm   Step Direction: **Pos** | Neg

Scan Increment: ⇕ 0.09525 mm   Data to Collect: Peak | **TOF**

Step Increment: ⇕ 0.09525 mm   Scan Start is At: **Center** | Corner

Scan Acceleration: ⇕ 127.00 mm/sec^2 **Bidirectional** | Compound | Line-in-Space

Scan Velocity: ⇕ 5.1223 mm/sec   **Aspect** | Max Scan Speed | Max Step Speed

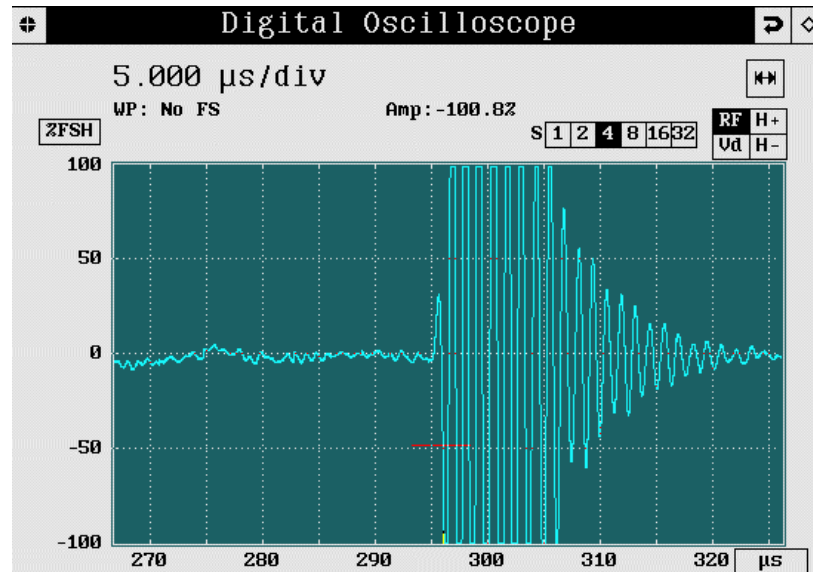| Step Speeds | Show Scan | Scan Number | Show All | | Go | OK | Cancel |

Fig. C3. Scan set-up window.

Fig. C4. Time gating leading edge of front surface echo.
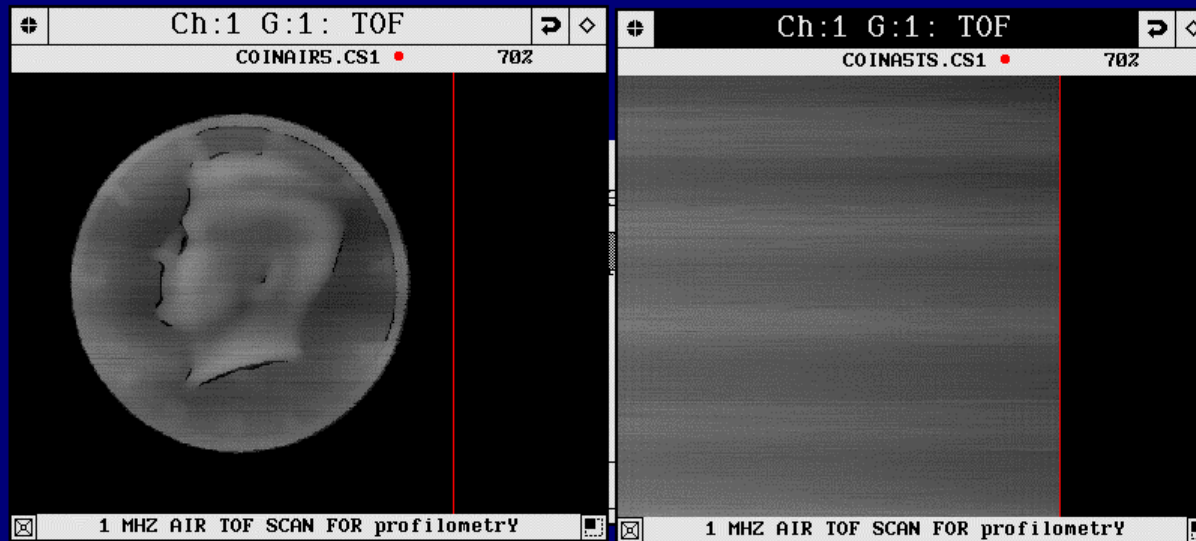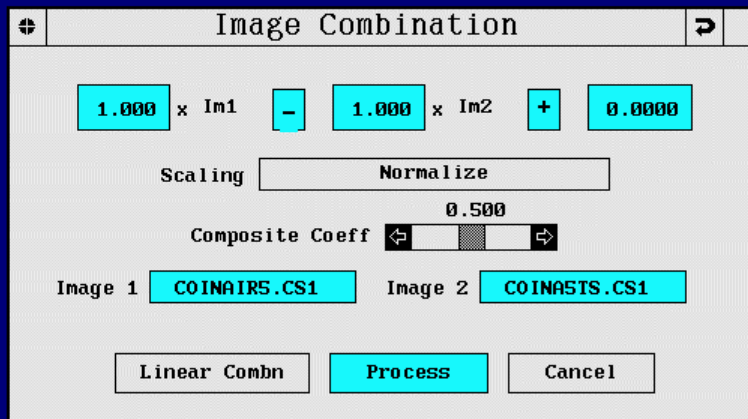
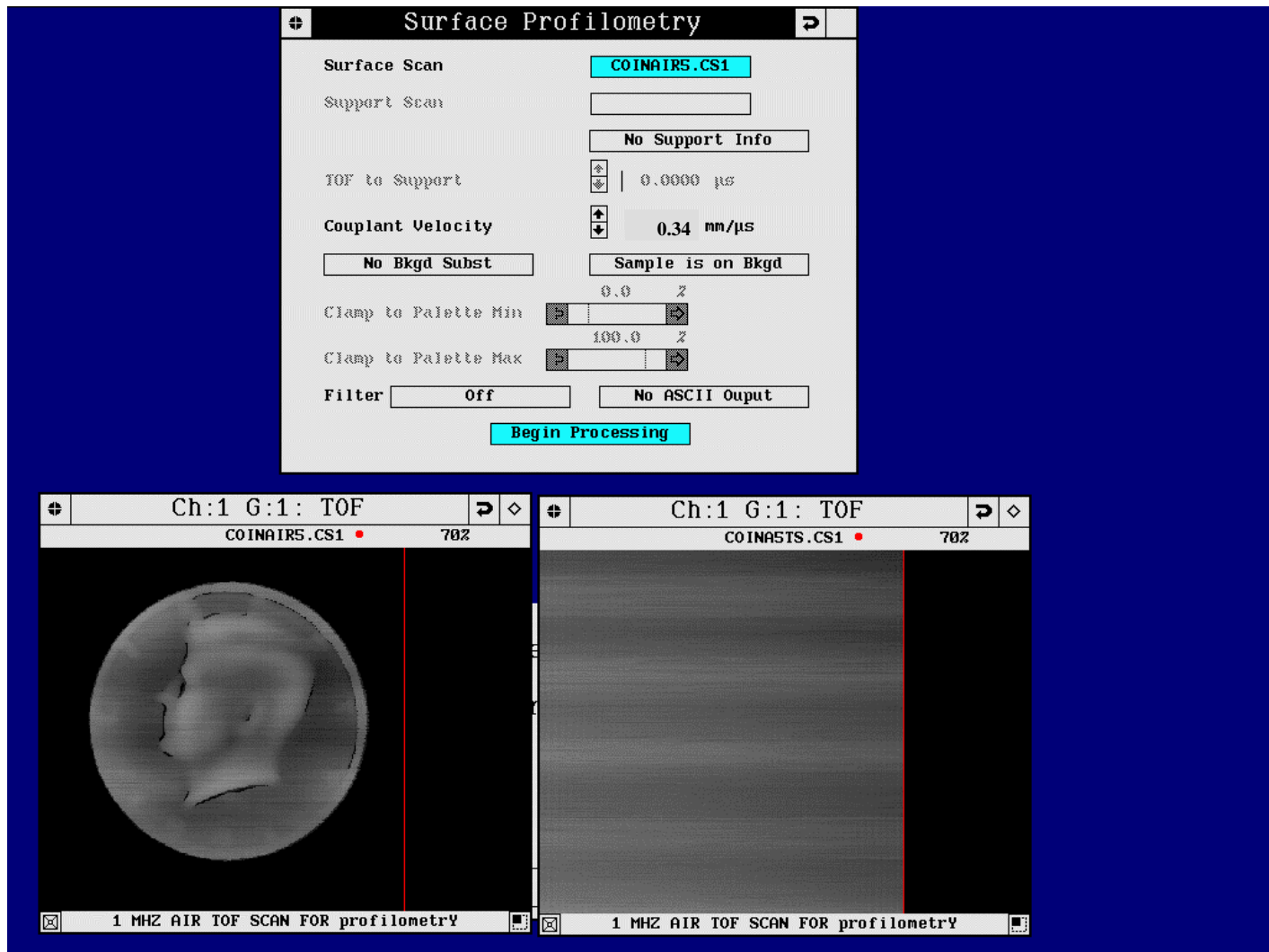Fig. C5. Add/Subtract (Image Combination) Window for leveling.
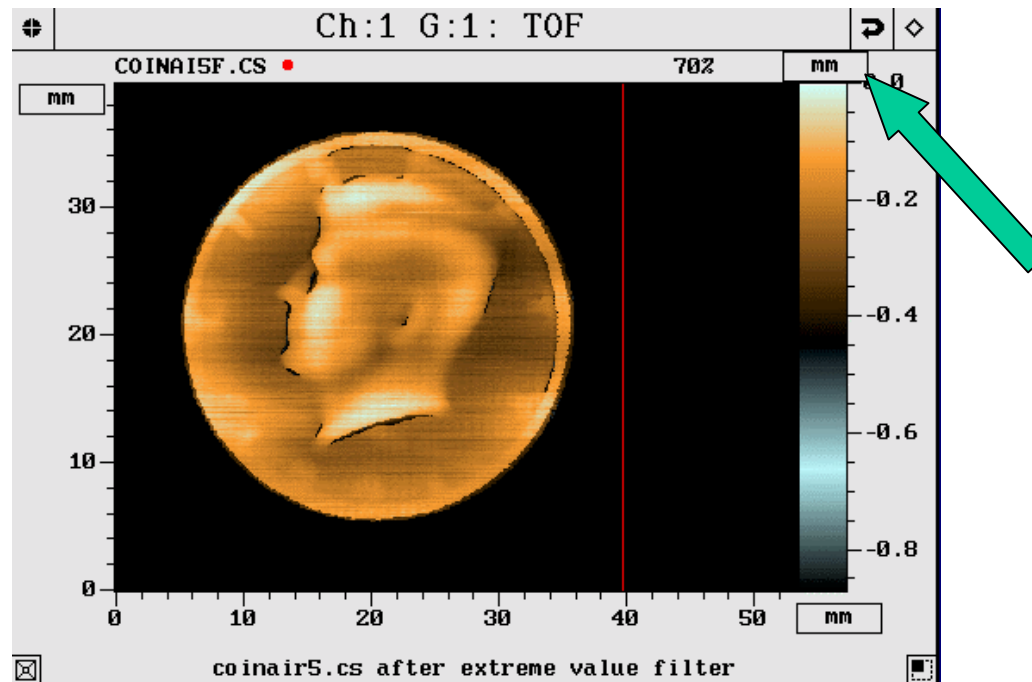
Fig. C6. Surface Profilometry Window.

Fig. C7. Toggle the units in the upper right-hand corner to display profile in terms of time (μsec) or distance (mm or in.).
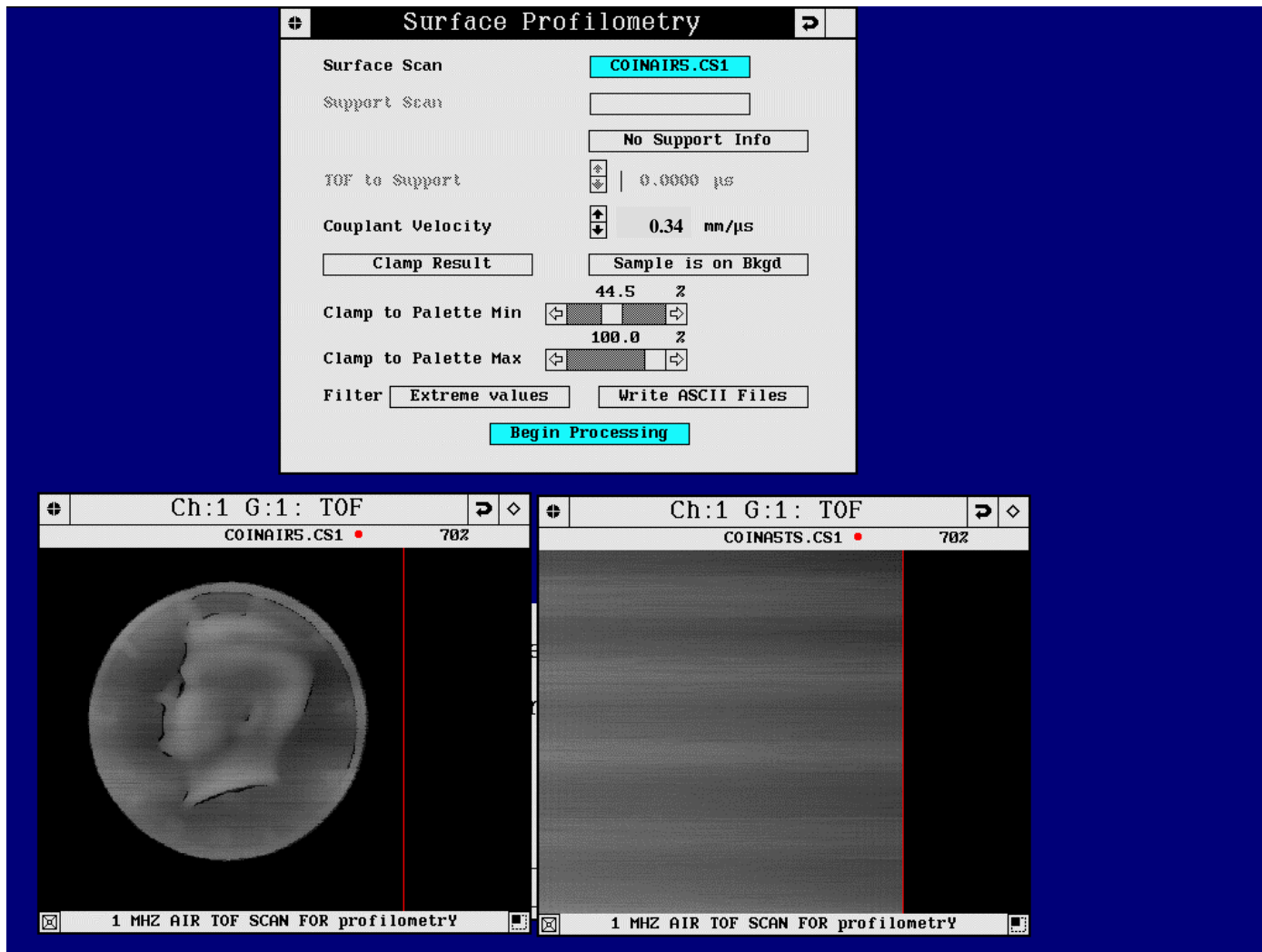
Fig. C8. Surface Profilometry Window showing extreme value filtering and write ascii files options.